Journal of the Saudi Heart Association

Volume 34 | Issue 4 Article 4

2022

Results of Surgical Ablation for Atrial Fibrillation in Patients with Rheumatic Heart Disease

Recommended Citation

Albacker, Turki B.; Alaamro, Sultan; Alhothali, Abdulaziz M; Arafat, Amr A; Algarni, Khaled D; Eldemerdash, Ahmed; and Bakir, Bakir M (2022) "Results of Surgical Ablation for Atrial Fibrillation in Patients with Rheumatic Heart Disease," *Journal of the Saudi Heart Association*: Vol. 34 : Iss. 4 , Article 4.
Available at: https://doi.org/10.37616/2212-5043.1321

ORIGINAL ARTICLE

Results of Surgical Ablation for Atrial Fibrillation in Patients with Rheumatic Heart Disease

Turki B. Albacker [a,*], Sultan Alaamro [a], Abdulaziz M. Alhothali [a], Amr A. Arafat [b], Khaled D. Algarni [c], Ahmed Eldemerdash [a], Bakir M. Bakir [a]

[a] Cardiac Sciences Department, College of Medicine, King Fahad Cardiac Centre, King Saud University Medical City, King Saud University, Riyadh, Saudi Arabia
[b] Department of Adult Cardiac Surgery, Prince Sultan Cardiac Centre, Prince Sultan Military Medical City, Riyadh, Saudi Arabia
[c] Cardiac Surgery Department, Johns Hopkins Aramco Hospital, Dhahran, Saudi Arabia

Abstract

Background: **There is conflicting evidence regarding the success of the Maze procedure to restore sinus rhythm in patients with rheumatic heart disease. Hence, the aim of our study was to describe the results of surgical ablation for atrial fibrillation in patients with rheumatic heart disease undergoing cardiac surgery.**

Methods: **This is a retrospective study that included adult patients with rheumatic heart disease who underwent surgical ablation for atrial fibrillation. The ablation lesions were performed using monopolar radiofrequency ablation in all patients.**

Results: **Fifty-seven consecutive patients were included in the study. Cox Maze IV was performed in 44 patients (77%), while left-sided surgical ablation was performed in 10 patients (17%) and pulmonary vein isolation in 3 patients (5%). The percentage of patients who were in sinus rhythm on discharge, at 1-month, at 3-months, 6-months and 12-months follow up were 56%, 54%, 52%, 56% and 46% respectively. Complete heart block occurred in 21 patients (44%), but only 15 of them (26%) required permanent pacemaker insertion. Freedom from composite endpoint of death, stroke, and readmission for heart failure was 78% at one-year follow up.**

Conclusion: **Despite the suboptimal rates of sinus rhythm at the intermediate and long term follow up, surgical ablation of atrial fibrillation in patients with rheumatic heart disease should continue to be performed. Continuation of Class III antiarrhythmic medications and early intervention for recurrent atrial fibrillation is crucial to the success of this procedure and for maintenance of higher rates of sinus rhythm at intermediate and long-term follow up.**

Keywords: Atrial fibrillation, Ablation, Cox maze procedure, Rheumatic

1. Introduction

Atrial fibrillation (AF) is prevalent in 45%−60% of patients with rheumatic heart disease (RHD) [1]. The effect of preoperative AF on reduced survival of patients undergoing cardiac surgery has been documented in many studies [2,3,4]. Restoration of sinus rhythm (SR), on the other hand, has been shown to improve survival in those patients [5,6].

However, the success of the Cox Maze procedure to restore SR in patients with RHD is limited with conflicting evidence. While some studies reported less satisfactory results in patients with RHD than patients with non-RHD [7], with a progressively decreased cure rate in the long term [8], others showed favorable results in patients with RHD during mitral valve surgery [9,10]. These controversial results could be attributed to the variations in Maze techniques using different lesions [11].

Hence, the aim of our study was to describe the results of our standard protocol for treating AF in patients with RHD undergoing cardiac surgery.

Received 26 September 2022; revised 16 November 2022; accepted 5 December 2022.
Available online 27 January 2023

* Corresponding author.
E-mail address: talbacker@ksu.edu.sa (T.B. Albacker).

https://doi.org/10.37616/2212-5043.1321

2. Methods

2.1. Study design and data collection

This retrospective study was conducted at a tertiary cardiac center. It included all adult patients with RHD above or equal to 18 years who underwent surgical AF ablation procedures from 2015 to 2020. Data were collected from electronic medical records, including patients' demographics, preoperative, operative and postoperative characteristics as well as follow up data. All ECGs were retrieved from the central electronic data of the non-invasive laboratory and reviewed for the purpose of this study. The Institutional Review Board approved the data collection of this study, and they waived the need for patients' consent because of the retrospective nature of the study.

2.2. Surgical technique

Our standard protocol for AF ablation is to perform left atrial (LA) surgical ablation (SA) or pulmonary vein isolation (PVI) for patients with paroxysmal AF, and Bi-atrial (BA) ablation (Cox Maze procedure) for patients with persistent or permanent AF. The BA SA lesions were performed according to the Cox Maze IV lesion set [12] using monopolar radiofrequency ablation (RFA) in all patients with persistent or permanent AF. All lesion sets were repeated three times to establish transmurality until a clear ablation line is observed in the atrial wall.

Left atrial appendage (LAA) was transfixed using interrupted U-shape mattress sutures using 4–0 Prolene. We did not use LAA occlusion clip because it is not available in our institution and we avoid the continuous purse string suture technique because it is associated with high rate of recanalization. All patients were started on a loading dose of Intravenous (IV) Amiodarone infusion then shifted to oral Amiodarone if their heart rate was above 80 beats per minute regardless of the rhythm (starting intra- or postoperatively). Patients with heart rate below 80 beats per minute were not started on any anti-arrhythmic medications to avoid significant bradycardia. All patients (including those with tissue or mechanical valves) were anticoagulated within 48 h with IV heparin for bridging, followed by oral warfarin for three months, then continued indefinitely if still in atrial fibrillation or if they had mechanical valves. Patients were followed routinely postoperatively at 1-month, 3-months, 6-months and 12-months periods then yearly after.

Abbreviations

AF	atrial fibrillation
AR	aortic regurgitation
AS	aortic stenosis
BA	biatrial
CAD	coronary artery disease
COPD	chronic obstructive pulmonary disease
EDD	end-diastolic diameter
ESD	end-systolic diameter
FU	follow up
HF	heart failure
IV	intravenous
LA	left atrial
LAA	left atrial appendage
LV	left ventricle
MR	mitral regurgitation
MS	mitral stenosis
MVR	mitral valve replacement
PAP	pulmonary artery pressure
PPM	permanent pacemaker
PVI	pulmonary vein isolation
RFA	radiofrequency ablation
RHD	rheumatic heart disease
RV	right ventricle
SA	sinu-atrial
TR	tricuspid regurgitation
TVr	tricuspid valve repair

2.3. Statistical analysis

Patients' characteristics were reported using mean and median values for continuous variables and proportion values for categorical variables. Kaplan–Meier curve was used to plot the freedom from the composite endpoint. Statistical analysis was performed using Stata 16.1 (Stata Corp- College Station- TX–USA).

3. Results

3.1. Patients' demographics and clinical characteristics

Fifty-seven consecutive patients were included in the study, of which 35 (61%) were females. Eleven patients (19%) had a preoperative history of stroke. Thirteen patients (23%) had Paroxysmal AF, 22 (39%) had permanent AF, and 22 (38%) had persistent AF. The predominant lesion was severe mitral stenosis (MS) in 25 patients (44%), severe mitral regurgitation (MR) in 23 patients (40%), severe aortic stenosis (AS) in 7 patients (12%), and severe aortic regurgitation (AR) in 2 patients (3%). Pulmonary hypertension was predominant in our cohort (89%) and two thirds of the patients (67%) had

moderate to severe tricuspid regurgitation (TR). The patient demographics and clinical characteristics are shown in Table 1.

3.2. Operative data

Cox Maze IV (BA SA) was performed in 44 patients (77%), while LA SA was performed in 10 patients (18%) and PVI in 3 patients (5%). Closure of LAA was performed in 39 patients (68%). Majority of patients underwent double valve procedure (67%). The commonest valve procedure was mitral valve replacement (MVR) that was performed in 41 patients (72%), followed by Tricuspid valve repair (TVr) (37 patients, 65%). Additional non-valvular procedures were performed in 16% of the cases. Operative data are shown in Table 2.

3.3. Postoperative complications

Thirty-one patients (54%) were in SR on the first postoperative day and continued in SR until discharge. Conduction abnormalities occurred in 21 patients (45%), but only 15 of them (26%) required permanent pacemaker (PPM) insertion. Only one patient (2%) developed perioperative stroke, and in-hospital mortality occurred in one patient (2%). Other postoperative data are illustrated in Table 3.

3.4. Follow up data

The median follow up (FU) period was six months (25th- 75th percentile: 1–12 months). During this period, three new patients (5%) developed stroke (all were in the AF group), six patients (11%) were readmitted with heart failure (HF), and mortality occurred in 2 patients (4%). Freedom from composite endpoint of death, stroke, and readmission for HF was 78% at one-year FU (Fig. 1). Patients who were discharged in SR continued with the same rhythm during the first 6 months of FU period (Fig. 2). The percentage of patients who were in sinus rhythm on discharge, at 1-month, at 3-months, 6-months and 12-months FU were 56%, 54%, 52%, 56% and 46% respectively. The percentage of patients with paced rhythm increased gradually over the FU period while the junctional rhythm rate decreased gradually. Additionally, there was an incremental trend in the percentage of atrial fibrillation after the 6th month of FU. There was an increase in the use of B-Blockers over the FU period, with a decrease in the use of Amiodarone and constant use of calcium channel blockers (Fig. 3).

Table 1. Preoperative data.

	(n = 57)
Age (years)	49 (46–58)
Female	35 (61%)
Saudi nationality	27 (47%)
Hypertension	29(51%)
Peripheral vascular disease	2 (4%)
COPD	3 (5%)
Smoking	6 (11%)
Chronic kidney disease	5 (9%)
Stroke	11 (19%)
Transient ischemic attack	1 (2%)
Diabetes mellitus	14 (26%)
Type of AF	
Paroxysmal	13(23%)
Permanent	22 (38.5%)
Persistent	22 (38.5%)
CAD	8 (14%)
Primary valve lesion	
Mitral stenosis	25 (44%)
Mitral regurgitation	23 (40%)
Aortic stenosis	7 (12%)
Aortic regurgitation	2 (3%)
Tricuspid regurgitation	
No	7 (12%)
Mild	12 (21. %)
Moderate	19 (33.5%)
Severe	19 (33.5%)
LV function	
Normal	39 (68%)
Mildly depressed	7 (13%)
Moderately depressed	7 (13%)
Severely depressed	4 (6%)
Pulmonary hypertension	51 (89%)
(mean PAP more than 25 mm Hg) PAP (mmHg)	55 (45–60)
LA size (cm)	5.2 (4.7–5.6)
ESD (cm)	3.2 (2.9–3.8)
EDD (cm)	4.9 (4.4–5.4)
RV function	
Normal	39 (69%)
Mildly depressed	8 (14%)
Moderately depressed	6 (10%)
Severely depressed	4 (7%)
RV dilatation	
No	35 (61%)
Mild	10 (18%)
Moderate	4 (7%)
Severe	8 (14%)

We presented continuous data as median (25th- 75th percentiles) and categorical data as frequencies and percentages.
(COPD: chronic obstructive pulmonary disease, CAD: coronary artery disease; RV: right ventricle, EDD: end-diastolic diameter, ESD: end-systolic diameter, LA: left atrium, LV: left ventricle, PAP: pulmonary artery pressure).

4. Discussion

Treating AF in RHD patients represents a real challenge to surgeons due to the low success rate and the high rate of late recurrence in those patients, as previously reported in multiple studies

Table 2. Operative data.

	(n = 57)
Mitral valve replacement	41 (72%)
Mechanical	12 (30%)
Tissue	28 (70%)
Mitral Valve size	29 (27–31]
Mitral valve repair	13 (23%)
Aortic valve replacement	13 (23%)
Mechanical	4 (31%)
Tissue	9 (69%)
Aortic valve Size	22 (21–23)
Tricuspid valve repair	37 (65%)
No. of valves replaced/repaired	
1	15 (26%)
2	38 (67%)
3	4 (7%)
Coronary artery bypass grafting	5 (9%)
Left atrial appendage closure	39 (68%)
Redo operation	7 (12%)
Ascending aorta replacement	1 (2%)
Atrial septal defect closure	3 (5%)
Type of ablation	
Bi-atrial	44 (77%)
Left Atrial	10 (18%)
Pulmonary vein isolation	3 (5%)
Intraoperative amiodarone	3 (5%)
Cardiopulmonary bypass time (minutes)	183 (155–217)
Cross Clamp time (minutes)	151 (125–182)

We presented continuous data as median (25th- 75th percentiles) and categorical data as frequencies and percentages.

[7,8]. However, even with the less favorable conversion rate compared to non-rheumatic patients, it is still compelling to perform surgical ablation in this group of patients to avoid the risks of long-term anticoagulation and the deleterious consequences of long-standing AF on heart function. We showed in our study that 54% of patients converted to SR immediately postoperatively and maintained SR during the first 6 months of FU. Other studies have shown similar results with variations in conversion rates between 40 and 75% over one-year FU [10,13,14]. The results of ablation for long standing AF in patients with rheumatic valve disease especially when combined with MV surgery were shown to be inferior to patients with lone AF or AF with non-rheumatic heart disease with freedom from AF recurrence ranging between 40 and 65% only [15,16]. However, most of these studies that showed higher rates of sinus rhythm in this group of patients (65–80%) in the mid-term follow up used additional ablation procedures and utilized chemical cardioversion for AF when discovered during FU [17,18,19]. This may explain the low rate of sinus rhythm in our patients during mid-term FU since we did not follow these strategies.

Table 3. Postoperative data.

	(n = 57)
Complete Heart Block	21 (45%)
Permanent Pace Maker (PPM)	15(26%)
Renal failure	26 (47%)
Max creatinine (μmol/L)	160 (140–190)
Stroke	1 (2%)
Re-exploration for bleeding	5 (9%)
Sternal wound infection	4 (7%)
Duration of MV (hours)	11 (7–15)
ICU stay (days)	6.5 (3–8)
Hospital stay (days)	12 (8–15)
Pericardial effusion	9 (16%)
Cardiac tamponade	3 (5%)
Hospital mortality	1 (2%)

We presented continuous data as median (25th- 75th percentiles) and categorical data as frequencies and percentages.

It has been demonstrated that paroxysmal AF originates from the pulmonary veins [20] and thus, in patients with this condition, a left atrial lesion set incorporating pulmonary vein isolation with or without additional lesions is generally sufficient. In those with more persistent forms of AF, triggers and reentrant circuits originating in the right atrium are thought to be responsible, and in these patients a right atrial lesion set is generally added [21]. This was the rationale for our strategy of performing LA SA or PVI for patients with paroxysmal AF, and BA SA for patients with persistent or permanent AF. The performance of LA SA or PVI was also advocated to decrease the number of lesions in order facilitate surgical ablation during minimally invasive surgery. Another advantage for left sided ablation techniques is to avoid the conduction abnormalities associated with BA SA. Although some authors have shown similar success rate of LA SA and PVI to BA SA [22,23], many studies have shown that left sided ablation procedures are inferior to BA SA in patients with long standing permanent or persistent AF and could result in a higher recurrence rate [24,25,26,27].

Multiple risk factors were suggested for AF recurrence in RHD patients, including body mass index, early AF recurrence [13], increased LA diameter, use of unipolar radiofrequency [14], longer AF duration, preoperative persistent or permanent AF, immediate postoperative AF, LA SA alone for persistent AF [28] and patient's age [29].

One of the important issues to overcome in ablating AF in RHD patients is the thickness of the atrial wall that is caused by fibrosis and degeneration of the atrial myocardium that has been implicated in the pathophysiology of disturbance of impulse propagation leading to AF in those patients [30]. This finding was confirmed by left atrial mapping studies demonstrating extensive left atrial scarring of diverse patterns [31]. In our study, we

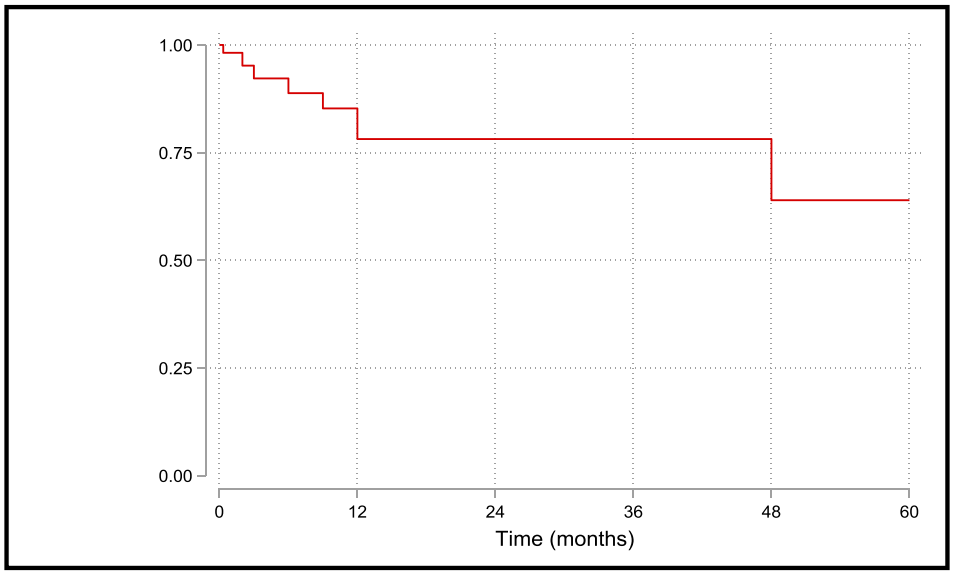
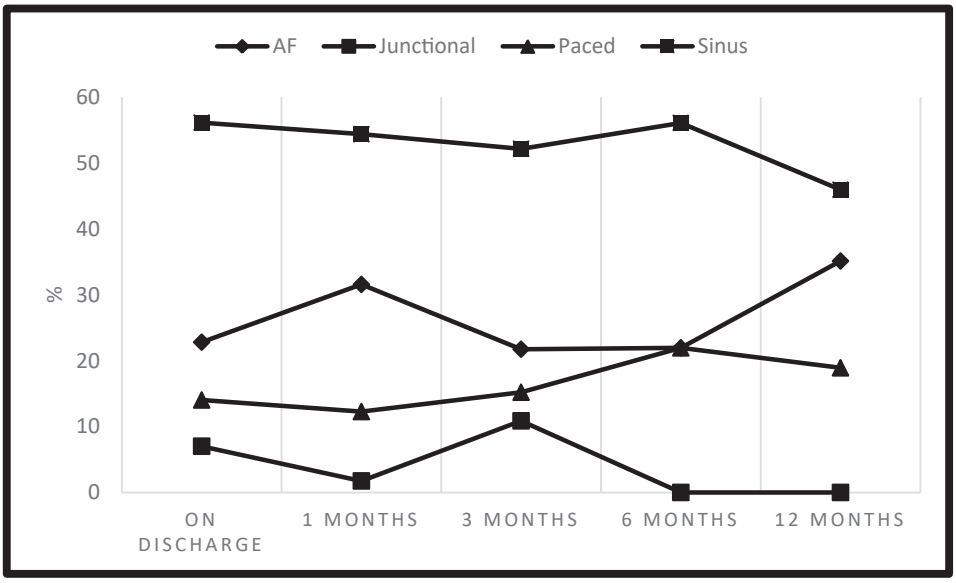


Fig. 1. Freedom from Composite endpoint of death, stroke, and readmission for heart failure.

repeated the lesion lines 3 times to ensure transmurality, especially in the thick atria involved with the rheumatic process. Some studies showed that unipolar RF can achieve comparable rates of SR after 1-year follow up to bipolar ablation independent of cardiac surgical procedure and of type of AF [32]. On the other hand, other studies showed that the use of bipolar ablation is superior to the unipolar surgical ablation of patients undergoing mitral valve surgery [33].

Another critical issue in maintaining SR post ablation is the continuation of antiarrhythmic medications during follow up visits. In our study, we showed an increase in recurrence of AF after six months; at the same time, the use of Amiodarone, as an antiarrhythmic medication, was decreasing with an increase in the use of B-blockers, which works more on rate control than rhythm control. Since this is a retrospective study, it is difficult to tease out whether cardiologists who were following those



(AF: atrial fibrillation)

Fig. 2. Follow up rhythm. (AF: atrial fibrillation).

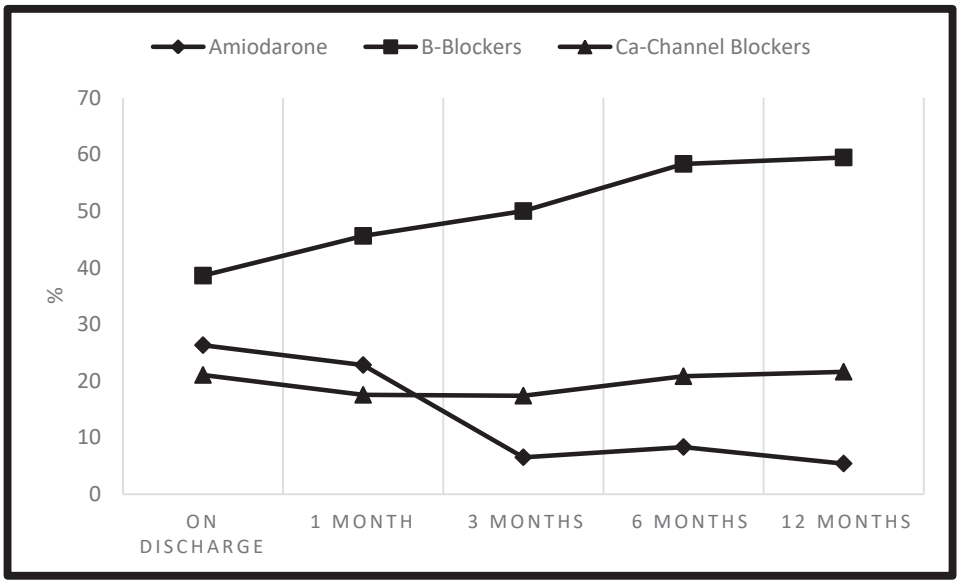


Fig. 3. Follow up anti-arrhythmic medications.

patients stopped Amiodarone because they do not have a clear protocol for how long to continue antiarrhythmic medications resulting in recurrence of AF or the patient had AF during their FU visits that led the cardiologists to follow the rate control strategy using B-Blockers. Either way, it is very important to educate our patients and their treating cardiologists on the importance of continuing class III antiarrhythmic medications on the intermediate and long-term FU. Ad N et al. [17] also recommended that careful follow up with antiarrhythmic drugs and/or cardioversion was required for the treatment of AF associated with RHD to enhance its success rate.

We also noticed in our study the high rate of conduction abnormalities post AF ablation requiring PPM insertion. Similarly, high rate of conduction abnormalities was reported by the CTSN investigators [34,35]. This could be related to the use of BA ablation in the majority of our patients that has been shown to be associated with high incidence of SA node dysfunction [36]. The incidence of SA node dysfunction post Maze procedure is more common in patients with long standing persistent atrial fibrillation especially when combined with MV surgery [37,38].

Although the percentage of patients with SR was only 54% post-ablation, it did not result in a high risk of stroke during the follow up period. We think that the LAA closure in most of our patients had an additional stroke prevention benefit, as shown previously in multiple studies [39,40].

To our knowledge, this is the first report of the results of surgical ablation for atrial fibrillation in Saudi Arabia. One of the strengths of our study was the standardization of our protocol, where all procedures were performed by the same surgeon, using the same technique, same energy source (RFA) and the same set of lesions for each type of AF.

5. Clinical implications

To our knowledge, this is the first report of the results of surgical ablation for atrial fibrillation in Saudi Arabia. Our findings support the performance of atrial fibrillation ablation in rheumatic heart disease patients going for cardiac surgery. However, our data showed an early discontinuation of class III antiarrhythmic medications that may have resulted in a lower rate of sinus rhythm at intermediate and long-term follow-up. Close FU and early management of AF recurrence is crucial for maintenance of sinus rhythm.

6. Limitations

The main limitation of the study is the retrospective design. The small number of patients is another limitation that did not allow further analysis of the factors leading to ablation failure or recurrence of atrial fibrillation in RHD patients. The use of unipolar radiofrequency ablation in this study may limit generalizability to bipolar ablation or ablation using other energy sources. Additionally, 24hr-holter ECG was not performed during postoperative follow up visits. Another limitation is the lack of

comparison of outcomes to the group of patients that did not have concomitant SA.

7. Conclusions

Despite the suboptimal rates of sinus rhythm at the intermediate and long term follow up, surgical ablation of atrial fibrillation in patients with rheumatic heart disease should continue to be performed. Continuation of Class III antiarrhythmic medications and early intervention for recurrent atrial fibrillation is crucial to the success of this procedure and for maintenance of higher rates of sinus rhythm at intermediate and long-term follow-up. Further studies are needed to investigate the high rate of conduction abnormalities in rheumatic heart disease patients and optimize the ablation techniques to minimize such risk.

Author contribution

Conception and design of Study: TBA, SA. Literature review: TBA, SA, AMA. Acquisition of data: SA, AMA. Analysis and interpretation of data: TBA, AAA, KDA, AE, BMB. Research investigation and analysis: TBA, SA, AMA, AAA, KDA, AE, BMB. Data collection: SA, AMA. Drafting of manuscript: TBA, SA, AMA, AAA, KDA, AE, BMB. Revising and editing the manuscript critically for important intellectual contents: TBA, SA, AMA, AAA, KDA, AE, BMB. Data preparation and presentation: TBA, SA, AMA, AAA, KDA, AE, BMB. Supervision of the research: TBA, KDA. Research coordination and management: TBA, KDA.

Acknowledgement

This study was supported by the College of Medicine Research Centre, Deanship of Scientific Research, King Saud University, Riyadh, Saudi Arabia.

Conflict of interest

None.

References

[1] Gillinov AM, Saltman AE. Ablation of atrial fibrillation with concomitant cardiac surgery. Semin Thorac Cardiovasc Surg 2007;19(1):25–32. https://doi.org/10.1053/j.semtcvs.2007.01.002. Spring;.

[2] Ngaage D, Schaff HV, Barnes SA, Sundt TM, Mullany CJ, Dearani JA, et al. Prognostic implications of preoperative atrial fibrillation in patients undergoing aortic valve replacement: is there an argument for concomitant arrhythmia surgery? Ann Thorac Surg 2006;82(4):1392–9. https://doi.org/10.1016/j.athoracsur.2006.04.004.

[3] Schulenberg R, Antonitsis P, Stroebel A, Westaby S. Chronic atrial fibrillation is associated with reduced survival after aortic and double valve replacement. Ann Thorac Surg 2010 Mar;89(3):738–44. https://doi.org/10.1016/j.athoracsur.2009.12.023.

[4] Ngaage DL, Schaff HV, Mullany CJ, Barnes S, Dearani JA, Daly RC, et al. Influence of preoperative atrial fibrillation on late results of mitral repair: is concomitant ablation justified? Ann Thorac Surg 2007 Aug;84(2):434–42. https://doi.org/10.1016/j.athoracsur.2007.04.036.

[5] Louagie Y, Buche M, Eucher P, Schoevaerdts JC, Gerard M, Jamart J, et al. Improved patient survival with concomitant Cox Maze III procedure compared with heart surgery alone. Ann Thorac Surg 2009 Feb;87(2):440–6. https://doi.org/10.1016/j.athoracsur.2008.10.001.

[6] Lee R, McCarthy PM, Wang EC, Vaduganathan M, Kruse J, Malaisrie SC, et al. Midterm survival in patients treated for atrial fibrillation: a propensity-matched comparison to patients without a history of atrial fibrillation. J Thorac Cardiovasc Surg 2012 Jun;143(6):1341–51. https://doi.org/10.1016/j.jtcvs.2012.02.006.

[7] Fukada J, Morishita K, Komatsu K, Sato H, Shiiku C, Muraki S, et al. Is atrial fibrillation resulting from rheumatic mitral valve disease a proper indication for the maze procedure? Ann Thorac Surg 1998 Jun;65(6):1566–9. https://doi.org/10.1016/s0003-4975(98)00135-0.

[8] Kim KC, Cho KR, Kim YJ, Sohn DW, Kim KB. Long-term results of the Cox-Maze III procedure for persistent atrial fibrillation associated with rheumatic mitral valve disease: 10-year experience. Eur J Cardio Thorac Surg 2007;31:261–6. https://doi.org/10.1016/j.ejcts.2006.11.017.

[9] Dong L, Fu B, Teng X, Yuan HS, Zhao SL, Ren L. Clinical analysis of concomitant valve replacement and bipolar radiofrequency ablation in 191 patients. J Thorac Cardiovasc Surg 2013 Apr;145(4):1013–7. https://doi.org/10.1016/j.jtcvs.2012.05.009.

[10] Sternik L, Luria D, Glikson M, Malachy A, First M, Raanani E. Efficacy of surgical ablation of atrial fibrillation in patients with rheumatic heart disease. Ann Thorac Surg 2010 May;89(5):1437–42. https://doi.org/10.1016/j.athoracsur.2010.01.047.

[11] Ad N, Suri RM, Gammie JS, Sheng S, O'Brien SM, Henry L. Surgical ablation of atrial fibrillation trends and outcomes in North America. J Thorac Cardiovasc Surg 2012;144:1051–60. https://doi.org/10.1016/j.jtcvs.2012.07.065.

[12] Lawrance CP, Henn MC, Damiano Jr RJ. Surgical ablation for atrial fibrillation: technique, indications, and resuts. Curr Opin Cardiol 2015;30:58–64. https://doi.org/10.1097/HCO.0000000000000125.

[13] Zhu X, Li Q, Li Y, Wu Z. Analysis of bipolar radiofrequency ablation in treatment of atrial fibrillation associated with rheumatic heart disease. PLoS One 2016;11(3):e0151248. https://doi.org/10.1371/journal.pone.0151248.

[14] Chavez EK, Colafranceschi AS, Monteiro A, Canale LS, Mesquita ET, Weksler C, et al. Surgical treatment of atrial fibrillation in patients with rheumatic valve disease. Braz J Cardiovasc Surg 2017;32(3):202–9. https://doi.org/10.21470/1678-9741-2017-0016.

[15] Chevalier P, Leizorovicz A, Maureira P, Carteaux JP, Corbineau H, Caus T, et al. Left atrial radiofrequency ablation during mitral valve surgery: a prospective randomized multicentre study (SAFIR). Arch Cardiovasc Dis 2009 Nov;102(11):769–75. https://doi.org/10.1016/j.acvd.2009.08.010.

[16] Doukas G, Samani NJ, Alexiou C, Oc M, Chin DT, Stafford PG, et al. Left atrial radiofrequency ablation during mitral valve surgery for continuous atrial fibrillation: a randomized controlled trial. JAMA 2005 Nov 9;294(18):2323–9. https://doi.org/10.1001/jama.294.18.2323.

[17] Ad N, Barnett S, Lefrak EA, Korach A, Pollak A, Gilon D, et al. Impact of follow-up on the success rate of the cryo-surgical maze procedure in patients with rheumatic heart disease and enlarged atria. J Thorac Cardiovasc Surg 2006 May;131(5):1073–9. https://doi.org/10.1016/j.jtcvs.2005.12.047.

[18] Han JS, Wang HS, Wang ZW, Yin ZT, Han HG, Tang CY. Safety and efficacy of Cox-maze III procedure for patients with atrial fibrillation associated with rheumatic mitral valve disease. Zhonghua Yixue Zazhi 2016 Apr 5;96(13):1011–5. https://doi.org/10.3760/cma.j.issn.0376-2491.2016.13.006.

[19] Gu J, Liu X, Jiang WF, Li F, Zhao L, Zhou L, et al. Comparison of catheter ablation and surgical ablation in patients with long-standing persistent atrial fibrillation and rheumatic heart disease: a four-year follow-up study. Int J Cardiol 2013 Oct 15;168(6):5372–7. https://doi.org/10.1016/j.ijcard.2013.08.057.

[20] Haïssaguerre M, Jaïs P, Shah DC, Takahashi A, Hocini M, Quiniou G, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Engl J Med 1998 Sep 3;339(10):659–66. https://doi.org/10.1056/NEJM199809033391003.

[21] Li H, Li Y, Sun L, Liu X, Xu C, Han J, et al. Minimally invasive surgical pulmonary vein isolation alone for persistent atrial fibrillation: preliminary results of epicardial atrial electrogram analysis. Ann Thorac Surg 2008 Oct;86(4):1219–25. https://doi.org/10.1016/j.athoracsur.2008.04.081.

[22] Cheema A, Vasamreddy CR, Dalal D, Marine JE, Dong J, Henrikson CA, et al. Long-term single procedure efficacy of catheter ablation of atrial fibrillation. J Intervent Card Electrophysiol 2006;15(3):145–55. https://doi.org/10.1007/s10840-006-9005-9.

[23] Phan K, Xie A, Tsai YC, Kumar N, La Meir M, Yan TD. Biatrial ablation vs. left atrial concomitant surgical ablation for treatment of atrial fibrillation: a meta-analysis. Europace 2015 Jan;17(1):38–47. https://doi.org/10.1371/journal.pone.0191354.

[24] Han FT, Kasirajan V, Kowalski M, Kiser R, Wolfe L, Kalahasty G, et al. Results of a minimally invasive surgical pulmonary vein isolation and ganglionic plexi ablation for atrial fibrillation: single-center experience with 12-month follow-up. Circ Arrhythm Electrophysiol 2009;2(4):370–7. https://doi.org/10.1161/CIRCEP.109.854828.

[25] Sef D, Trkulja V, Raja SG, Hooper J, Turina MI. Comparing mid-term outcomes of Cox-Maze procedure and pulmonary vein isolation for atrial fibrillation after concomitant mitral valve surgery: a systematic review. J Card Surg 2022 Nov;37(11):3801–10. https://doi.org/10.1111/jocs.16888.

[26] Bogachev-Prokophiev AV, Afanasyev AV, Pivkin AN, Ovcharov MA, Zheleznev SI, Sharifulin RM, et al. A left atrial versus a biatrial lesion set for persistent atrial fibrillation ablation during open heart surgery. Eur J Cardio Thorac Surg 2018 Oct 1;54(4):738–44. https://doi.org/10.1093/ejcts/ezy126.

[27] Cappabianca G, Ferrarese S, Tutino C, Corazzari C, Matteucci M, Mantovani V, et al. Safety and efficacy of biatrial vs left atrial surgical ablation during concomitant cardiac surgery: a meta-analysis of clinical studies with a focus on the causes of pacemaker implantation. J Cardiovasc Electrophysiol 2019 Oct;30(10):2150–63. https://doi.org/10.1111/jce.14117.

[28] Pecha S, Schäfer T, Subbotina I, Ahmadzade T, Reichenspurner H, Wagner FM. Rhythm outcome predictors after concomitant surgical ablation for atrial fibrillation: a 9-year, single-center experience. J Thorac Cardiovasc Surg 2014 Aug;148(2):428–33. https://doi.org/10.1016/j.jtcvs.2013.08.074.

[29] Gillinov M, Soltesz E. Surgical treatment of atrial fibrillation: today's questions and answers. Semin Thorac Cardiovasc Surg 2013;25(3):197–205. https://doi.org/10.1053/j.semtcvs.2013.09.003. Autumn.

[30] Bailey GW, Braniff BA, Hancock EW, Cohn KE. Relation of left atrial pathology to atrial fibrillation in mitral valvular disease. Ann Intern Med 1968 Jul;69(1):13–20. https://doi.org/10.7326/0003-4819-69-1-13.

[31] Shankar PRB, Roa BH, Jaishankar S, Narasimhan M. Current perspectives: rheumatic atrial fibrillation. J Atr Fibrillation 2010 Mar 1;2(5):222. https://doi.org/10.4022/jafib.222.

[32] Schäfer T, Pecha S, Ahmadzade T, Subbotina I, Reichenspurner H, Wagner FM. Event-recorder monitored rhythm-outcome after uni- vs. bipolar ablation therapy for concomitant atrial fibrillation in cardiac surgery. Thorac Cardiovasc Surg 2013;61:182. https://doi.org/10.1016/j.jtcvs.2014.02.061.

[33] Canale L, Azevedo B, Correia M, Chavez E, Macedo E, Mattoso C, et al. Bipolar versus unipolar energy in the surgical ablation of atrial fibrillation in patients with mitral valve surgery. Heart, Vessels and Transplantation 2018;2:81. https://doi.org/10.24969/hvt.2018.81.

[34] Gillinov AM, Gelijns AC, Parides MK, DeRose Jr JJ, Moskowitz AJ, Voisine P, et al. Surgical ablation of atrial fibrillation during mitral-valve surgery. N Engl J Med 2015 Apr 9;372(15):1399–409. https://doi.org/10.1056/NEJMoa1500528.

[35] DeRose Jr JJ, Mancini DM, Chang HL, Argenziano M, Dagenais F, Ailawadi G, et al. CTSN investigators. Pacemaker implantation after mitral valve surgery with atrial fibrillation ablation. J Am Coll Cardiol 2019 May 21;73(19):2427–35. https://doi.org/10.1016/j.jacc.2019.02.062.

[36] Cho MS, Heo R, Jin X, Lee JB, Lee S, Kim DH, et al. Sick sinus syndrome after the maze procedure performed concomitantly with mitral valve surgery. J Am Heart Assoc 2018 Oct 2;7(19):e009629. https://doi.org/10.1161/JAHA.118.009629.

[37] Pasic M, Musci M, Siniawski H, Edelmann B, Tedoriya T, Hetzer R. Transient sinus node dysfunction after the Cox-maze III procedure in patients with organic heart disease and chronic fixed atrial fibrillation. J Am Coll Cardiol 1998 Oct;32(4):1040–7. https://doi.org/10.1016/s0735-1097(98)00358-1.

[38] Kulikov AA, Bokeria LA. Assessment of sinoatrial node function in patients with persistent and long-standing persistent forms of atrial fibrillation after maze III procedure combined with mitral valve operation. J Atr Fibrillation 2016 Jun 30;9(1):1408. https://doi.org/10.4022/jafib.1408.

[39] Yao X, Gersh BJ, Holmes Jr DR, Melduni RM, Johnsrud DO, Sangaralingham LR, et al. Association of surgical left atrial appendage occlusion with subsequent stroke and mortality among patients undergoing cardiac surgery. JAMA 2018;319(20):2116–26. https://doi.org/10.1001/jama.2018.6024.

[40] Whitlock RP, Belley-Cote EP, Paparella D, Healey JS, Brady K, Sharma M, et al. Investigators. left atrial appendage occlusion during cardiac surgery to prevent stroke. N Engl J Med 2021 Jun 3;384(22):2081–91. https://doi.org/10.1056/NEJMoa2101897.